Disclosure
Ubiquitous Interconnectivity of In-Home Consumer Appliances

Abstract
The ability to interconnect consumer entertainment appliances and PCs within a consumer household is described. This in-home network is "plug-and-play," enabling consumers to add specific service features, broadband information access appliances, entertainment appliances, and / or PC appliances at any physical location, at any time to extend the enjoyment of the home. These extensions can encompass entertainment means, e-Commerce means, home management and security means, personal video recording means, and home computing means. These home enjoyment extensions can be made without any need to cable in-between appliances nor any need to "set-up" appliances following some installation instructions that come with the appliances, or as contained within some "help" or "read me first" soft file contained within the appliance. The in-home network is "plug-and-play;" the generic features are illustrated in Figure 2.

Description of Invention
Figure 3 illustrates the "in-home network." Node #1 (more fully illustrated in Figure 4) is the home portal or home gateway, which enables broadband access of in-home services, broadband information access appliances, entertainment appliances, and / or PC appliances to / from broadband service / entertainment channels external to the home.

By way of further illustration, Node #2 in Figure 3 is an entertainment appliance. In this instance, Node #2 is a network facilitated TV set. Node #3 is a network facilitated PC appliance. Node #4 is a second network facilitated TV set. Node #5 is a large network facilitated storage device (whose features are illustrated in Figure 5) that can host home entertainment media, home management media, and home security media. This storage device can also host software programs for home security and management, and can access networks and services external to the home as required by indications from home status sensors.

Node #6 is a network facilitated link to the home security sensors. Node #7 is a network facilitated link to a lighting device. Node #8 is a network facilitated medical emergency call actuator.

Going on to Figure 6, Nodes #9 and #10 are representative of a network facilitated CD quality audio system. The network also can be facilitated voice communication appliances where intra-home communications are enabled as well as voice communications external to the home. These voice communications appliances can be personal in nature.

Node #11 is representative of a network coupling external to the home. Such external couplings enable in-home appliances to be moved / relocated external to the home in such locations as around a swimming pool, patio, and the like, so as to extend the intra-home network functionality externally to its near by surroundings.

Home Portal / Gateway
Figure 4 illustrates this home portal that access external broadband and narrow band services. In this illustration, a microwave antenna is shown. This antenna maybe accessing some MMDS or LMDS or DBS service, and these services may be bi-directional in nature.

For the specific illustration, the home portal includes a "TV channel tuner." The purpose of this tuner is to pre-select one or more service channel(s) from the broadband MMDS or LMDS or DBS links for distribution onto the home network at any specific instance of time. For each service channel selected, means is provided within the home portal to select that specified channel. For example, if some combination of six TVs and PCs have selected six distinct service channels, then six channel selector means are provided for in the home portal. If ten concurrent service channels are to be provided for, them ten service channel selection means are provided.

To manage bi-directional communication over braodband or narrow band external services, an adaptive information router is provided. In the instance of Figure 4, this router is illustrated in conjunction with xDSL service, and is a Reconfigurable ATM Adaption Layer 2 device. A xDSL modem [not illustrated] interfaces the Reconfigurable ATM Adaptation Layer 2 device to the actual Layer 1 interface with the external POTS lines.

In a similar way, this interface could be with a microwave frequency return paths.

The functionality of the Reconfigurable ATM Adaptation Layer 2 device is more fully described in Appendix I of the Figures attached to this disclosure.

The home portal also provides for logic means such that the baseband outputs from the service channel tuners and a Reconfigurable ATM Adaption Layer 2 devices, encrypt, add specific destination headers, modulate and deliver to the RF transceiver radio circuits. In a similar way, this logic means takes the also receives the baseband return paths from the RF transceiver radio circuits and delivers the information to internal control means and / or the adaptive information router.

The RF transceiver radio circuits output a modulated radio signal on one of the diversity antennas, as well as being able to receive signals on both diversity antennas. Polarization diversity may be employed as a further improvement to the diversity capability of the receiver in addition to the spatial diversity implemented in the logic section of the receiver. Functioning as a sending device, these RF transceiver radio circuits modulate the carrier(s) with the baseband information, amplify these signals, and drive the transmit antenna. Functioning in a receiver mode, these RF transceiver radio circuits block down convert the available block of channels and deliver this RF frequency block to the channel tuner means as more fully illustrated in Figures 7 and 8. The specifics of this channel tuner device are more completely described in Figures 18 through 26, and in Case #13,580. The transceivers are intended to operate in the 5.6 Ghz UNI-I band at a power level of less than one watt.

Network Implementation

Figures 9 through 13 illustrate the network communication scheme. In particular, Figures 10 and 12 fully describe the architectural software and hardware layers that comprise the logic means of Figure 2. What is not shown in Figures 10 and 12 is the encryption and de-encryption means that may be used to secure intra-home communications from security breaches, and a microprocessor control means. This microprocessor control means handles the self registering network process describing its functionality and availability of the appliance to all other nodes on the network, and for controlling bilateral communications between network appliances individually and bilaterally with Node #1 in Figure 4.

The QAM modulation method has been selected for the home network over other available choices. In making this selection, the technical criteria are illustrated in Figure 14, while Figure 15 compare the value of the QAM selection over, say an alternative choice of COFDM, and Figure 16 illustrates means for further adapting QAM to handle in-home multipath conditions.

Spatial Diversity Combiner

This means, as illustrated in Figure 17, and more fully described in Case #'s 13,775 and 13,776 has been selected to adapt the QAM system to multipath transmission conditions within the home environment.

Technical and Competitive assessments

Attachments I and II provide added discussion materials as to the technical risks associated with the example in-home networking technology and how these risks are mitigated. Attachment II deals with the competitive landscape and how the technological approach represented in this disclosure overcomes current state-of-the-art limitations.

Attachment I
Technical Risk Assessment

1. Home Multipath

The home environment is such that signals will arrive at a receiver, where each signal has followed a different path (multipath). Signal reflections, for example, can give rise to multipath conditions. Dealing with multipath conditions (sometimes called ghosts), both static and dynamic (signals bouncing off of moving objects like people), is a Sarnoff technological strength -- as exemplified by the second generation 8-VSB ATSC "ghost busting" signal demodulator offering from Sarnoff / Motorola.

For the home environment, the architecture envisions a dual antenna configuration at the receiver where each antenna is optimized to receive a different signal polarization, i.e., horizontal and vertical. The architecture then employs a "spatial diversity combiner" to optimize these two signals as received by the dual antenna configuration to produce the best "combined" signal.

The concept of a "diversity combiner" has been employed in the cellular telephone industry since the '70's. The diversity combiner technology has proven to be successful in combating multipath. More robust spatial diversity combiner technology is being evaluated by ATT's PCS system, with an experimental cell sight in Red Bank, NJ. Other major cellular equipment providers also are evaluating spatial diversity combiners.

In approaching the Home Wireless Network, the architecture accomplishes several goals:

> **Data rate**: For handling DBS DTV feeds, channel data rates within the home must approach 40 Megabits/sec.
>
> **Low cost** (<$50 retail adder per node): The overall system architecture must intrinstly enable "low cost." NewCo's current estimates are under the accepted goal of <$50. This is a direct consequence of the overall architecture, including the simple channel transmission protocol that needs only to look for a "free" channel.
>
> **Near neighbor interference**: To keep near neighbors in apartments, town homes, condos, etc., from potentially interfering with each other, the total number of available channels must be large. At 5.6GHz, NewCo is offering approximately 65 channel selections.

Given the constraints of data rate, low cost, and near neighbor interference, there is the potential technical risk that this architecture will not achieve satisfactory levels of multipath "de-ghosting."

What are the multipath risk mitigation tactics available?

> **Increase channel bandwidth on the order of 20%**: The 256-QAM-symbol constellation presents itself as an array of 16 x 16 symbols. The spacing between the symbols as transmitted is directly proportional to the ability of the QAM demodulator to mathematically separate the array into a distinct set of symbols, given a level of channel noise, like multipath. Increasing the NewCo's channel bandwidth from 6MHz to a little over 7MHz may enable the demodulators to deal with higher levels of multipath.
>
> **Reduce the modulation system to 128- or 64-QAM**: Within the same bandwidth, reducing the size of the symbol constellation increases symbol spacing and enhances the system's ability to deal with elevated channel noise. But to keep the same data rates, the bandwidth must be increased, perhaps on the order of 30%. (For comparison, DBS down links use a 4-QAM constellation and 24MHz of bandwidth at a 40Meagbit/sec. channel rate.)

Optimized QAM: A derivative approach wherein the constellation is configured as a "circle" rather than as a 16 x 16 square array. The result is enhanced symbol spacing within the same bandwidth.

COFDM: Robust in dealing with multipath, COFDM doubles the bandwidth requirement to about 12 MHz. This consequently introduces stringent demands on the RF circuit designers, the selection of A/D and D/A signal conversion components for control of system phase noise (ultra linear RF circuits, high resolution data converters), and opens the door wider to potential interference between near neighbors.

2. System Phase Noise

Phase distortion introduced by system components as well as by the wireless transmission environment is cumulative and is a difficult component for a QAM system to correct "after the fact" within the demodulation system. In general, the entire system is designed to minimize the components that contribute to phase distortion. These design steps include:

RF circuits: RF circuits must be designed with careful attention to amplitude and phase linearity over the bandwidth of the channel. Keeping system bandwidth to a minimum makes this challenge easier.

System timing: Jitter in the system's phase locked loops (PLL) and voltage controlled oscillators (VCO) must be tightly controlled. Sarnoff has proven PLL and VCO technology available to Sarnoff as disclosed in Patent Nos. 5,497,127; 5,731,743.

Signal conversion precision/resolution: The signal converters (A/D and D/A) within the system need to exhibit precision (as reflected in differential non-linearity [DNL] and in the effective-number-of-bits [ENOB] specifications, for example) and resolution. Sarnoff has proven CMOS signal converter technology that achieve the necessary performance parameters. This technology will be available to Sarnoff as disclosed in Patent Nos. 5,262,779; 5,272,481; 5,471,208; 5,500,612.

What is the phase noise risk mitigation tactic available?

Compromise bandwidth: Increasing bandwidth can enhance the signal-to-noise performance of the transmission channel. This increase can be used to offset under performance of system circuits. The maximum bandwidth increase available is about 20%.

3. Signal Penetration of Walls

Preliminary industry studies that have been performed indicate that signal penetration should be a problem. For example, sheet rock should pose only minimal problems for signal penetration at 5.6GHz. Concrete blocks and office construction techniques may impose greater signal limitations. If these limitations prove to be severe, compartment architectures would be employed.

Attachment II

Disclosed Ubiquitous Interconnectivity of In-Home Consumer Appliances

... compared to...

State of the Art Technical Approaches

1. Market Drivers, Technical Need, and Market Size

The underlying need behind home networking is enabling consumer electronic devices to communicate with each other easily and cost effectively. With broadband to the home becoming more and more of a reality, broadband within the home is very likely to follow. Credit Suissee First Boston Corporation, in a equity research report dated August 9, 1999, set forth the market drivers for broadband home networking:

> **Bandwidth**: As increases in microprocessor and memory availability at lower costs have fueled rapid expansion of PC applications, cheap and abundant bandwidth will fuel "an insatiable appetite" for home applications and services.
>
> **Device diversity**: "We strongly believe that the world is moving towards multiple specialized devices rather than an all-encompassing general purpose device, which paves the way for extensive networking requirements."
>
> **Application proliferation**: Driving the initial demand will be early consumer acceptance of applications enabling Internet sharing, etc. Second stage market demand will incorporate not just PC-related devices, but also TVs, personal digital video recorders (PVRs), and digital versatile disk (DVD) players. Applications that enable home synchronization of these "smart" consumer appliances will continue to emerge, taking advantage of the growing acceptance of networked devices by consumers.
>
> While information exchanges are likely to continue as the consumer's motivator as the market enters this second stage of growth, consumers are very likely to appreciate the benefits of having multiple devices, including TVs, connected to the Internet. With "always-on" broadband interconnection to the home expected to become highly pervasive by 2003, the abilities of the disclosed broadband home wireless to deliver Internet to the TV (and PCs) will become a major market up-surge driver.
>
>> The disclosed home wireless network is entering this broadband home wireless market positioned at the precise point of the market's "second stage."
>>
>> Product back filling to support first stage market demand could be accomplished by the disclosed network with "PC-Bridge" devices, so as to enable PC to be operated from TVs, PVRs to be operated from either PCs or TVs, PCs to access broadband home hubs, etc.
>
> **Standardization and low cost**: Standards serve a pivotal role in determining the competitive landscape over time. Sarnoff's approach is not yet an industry standard. Current standards in this market space do not answer this need for data rates of 40-Mbits/sec in the 5.6GHz band.
>
>> DirecTV's high-definition TV (HDTV) service requires a data rate of 31 Mbits/sec between the output of the quadrature phase shift keying (QPSK) demodulator and the input to the transport demultiplexer.

The disclosed product vision is that the QPSK demodulator is located within the broadband home portal, with the transport demultiplexer / decriptor located within the wireless set-top-box (STB) or digital TV (DTV).

The disclosed visonary architecture is to pre-select the 6MHz digital TV (DTV) channel at the broadband portal and then transmit only the selected channel "wirelessly" to the TV. This architecture minimizes in-home transmission of unneeded bandwidth; enabling availability of a larger number of useful full duplex channels, and minimizing the need for sophisticated transmission protocols to handle traffic (low cost).

The closest standard to meeting this data rate need is Hiperlink. But on a steady state transmission basis, Hiperlink supports only a fraction of its stated 54Mbits/sec. burst speed. Hiperlink also provides only 16 full duplex channels for each of the 200MHz bands available at 5.6GHz.

In contrast, the disclosed technology provides up to 32 full duplex channels at nearly 40 Mbits/sec in each of the two 200MHz bands at 5.6GHz. With a potential of 64 channels, "interference" opportunities within apartment buildings, condos, and town home environments are minimal, meaning that transmission protocols need only select an "available" duplex channel.

Sarnoff is expecting to establish the defacto standard.

Life style changes: Personal, family, and professional lives are becoming much more interwoven. Access to information is growing in importance. The Internet has become a major factor in harmonizing educational, social, medical, and economic issues within the family, and in bringing these experiences into the home. To continue pervasive connectivity will be required within the home.

The First Boston report indicates that multi-PC homes will be the most likely "early adopters" of broadband home wireless, and that the growth in multi-PC homes will be experiencing double-digits through 2002. First Boston further forecasts:

- The total available market (TAM) for "home wireless," which is defined as the multi-PC homes, will be 24 million by the end of 2002.
- The "home wireless" penetration by the end of 2002 to be 50% of the TAM, or 12 million homes.
- There will be 28 million "wireless" nodes representing the installed base by the end of 2002 (two to three nodes per home).

The Consumer Electronics Manufacturing Association (CEMA), in a 1998 study, characterized "PC-homes" as:

- owning more TVs per home,
- having two or more VCRs per home,
- buying the larger screen TVs,

- having the highest familiarity with set-top-boxes (STB), modems, and the like, and understanding DTV better

than the US population on a whole. This, then, is the market demographics that are most likely go for the disclosed "broadband (video) home wireless."

The general willingness of the US consumer during the first half of 1999 to accept new home technology is the relatively high penetration rates of:

- on-line services (30% all homes / 56% PC homes),
- multiple PCs (13% all homes / 24% PC homes),
- multiple phone lines (29% all homes / 40% PC homes),
- modems (42% all homes / 78% PC homes),
- call waiting (45% all homes / 54% PC homes),

suggests <u>a limited fear factor of new technology and an growing technologically savvy consumer</u>.

FINAL NOTE: A June 1997 CEMA study found that 44% of all the homes surveyed would be interested / very interested in watching a VCR tape from a <u>single</u> VCR from any TV in the home; 61% are interested / very interested in watching cable or satellite TV on any TV within the home; and 41% would like to access their PC from any TV in the home. (sounds like the home wireless market).

2. Introduction

The market need for a Broadband Wireless Home Network solution stems from the pervasive need to distribute broadcast quality video, along with voice over IP, and other simultaneous wideband applications for internet and data in the small office and home office (SOHO) environment.

Several technologies currently exist for meeting the moderate to low speed data rate wireless market and provide unhindered data rates to 11-Mbits/sec. Other technologies are in the planning stages and before the existing standards bodies to address some of these market needs. Some technologies, such as an industry standard like Bluethooth, exist to meet another set of market needs where speed is not critical, but interconnectivity defines the product feature set.

Spectrum availability is a critical resource especially considering the raw bit-rate required for wireless multimedia applications. The suitability of the various licensed frequency bands such as those used for cellular, personal communications systems (PCS) and Wireless Local Loop technology is presented in Section 3. Higher bit rates typically require greater spectrum. Section 4 discusses the utilization of bandwidth for the Broadband Wireless Home Network solution and other competing wireless standards. Finally a brief discussion of technical merits and pitfalls is presented is Section 5.

Table I

Standard or Name	Technology/Freq	Data Rate
802.11, 802.11b	DSSS*/2.4 GHz	11-Mbits/sec
Wavelan (Lucent Tech)	DSSS/2.4 GHz	11-Mbits/sec
HomeRF	Slow Frequency Hopped FSK* modulation /2.4 GHz	1 Mbit/sec
SWAP	Same as HomeRF but using 4FSK	1.6 Mbit/sec
Bluetooth	Slow Freq Hopped/DSSS	723.2 Kbits/sec
802.15	See Bluetooth	See Bluetooth
802.11a	OFDM*/5 GHz	≤ 25 Mbits/sec
BRAN	See 802.11a	See 802.11a
Hiperlan	See 802.11a	See 802.11a
MMAC	See 802.11a	See 802.11a
Hiperlink	OFDM/17 GHZ	25 – 155 Mbits/sec

* NOTE: DSSS is Direct Sequence Spread Spectrum
FSK is Frequency Shift Keying
OFDM is Orthogonal Frequency Division Multiplex

3. Licensed Frequency Applications

Licensed frequency band devices and applications such as the cellular frequency band near 800 MHz and the PCS bands at 1900 MHz are not considered for this application. The mixing of wireless multimedia with mobile telephone / PCS applications has yet to produce an effective or cost effective solution or alternative for the wireless multimedia market. Although some technologies are moving toward technical capability to provide low to medium data rates, the cost burden for these *services* will continue to require that this capability be used to address a very different market segment. At the technical level, group special mobile (GSM), code division multiple access (CDMA) and wide-band code division multiple access (WCDMA) have all made advances to provide higher data rates to users, but still fail to break the 2 Mbit/sec barrier. WCDMA solutions such as Japan's DoCoMo standard (a WCDMA technology variant) offers good data rate capability for wireless web browsing but insufficient capability to support data rates for 20 Mbit/sec for wireless multimedia applications.

Other services such as Metropolitan Multipoint Distribution Service (MMDS) at 2.5GHz, Local Multipoint Distribution Service (LMDS) at 24 and 38 GHz, offer higher data rates to the home delivery service but lack the essential interactive and "plug and play" type of flexibility needed to drive and support the in-home Broadband Wireless Home Network concept.

4. Spectrum Allocations

The preferable spectrum allocation is one that offers sufficient bandwidth to support multiple wireless multimedia applications without interference and at minimal cost. The cost issue referrers to both a cost free (unlicensed) frequency band and one requiring low component cost for implementation. The bands of choice are the so-called Instrument, Scientific and Medical (ISM), bands specified by the FCC.

In the United States, these bands exist from 902 to 928 MHz, at 2.4 GHz and 5.6 GHz. The useable bandwidth near 900 MHz is 26 MHz and 80 MHz at 2.4 GHz. In the 5.6 GHz band, also referred to as the Unlicensed National Information Infrastructure Devices (U-NII) band, two non-contiguous blocks of 200 MHz each are available. Further, similar bands in the 5 GHz region have gained acceptance throughout the world for similar use.

5. Technical Pros and Cons

The IEEE Standards 802.11 and "802.11b like" LAN and wireless LAN technologies lack the bandwidth and raw bit rate capability to address the wireless multimedia market needs. In addition, the low chip-to-bit ratio spreading sequence, an 11-bit Barker sequence, is insufficient to provide a reasonable amount of processing gain to allow the overlay of multiple devices as would be needed to fully address the wireless multimedia market.

In July 1998, the IEEE 802.11 standardization group selected the orthogonal frequency-division multiplexing (OFDM) as the basis for the new 5 GHz standard, targeting a range of data rates from 6 up to 54 Mbits/sec. Currently described by 802.11a-1999, this new standard is the first to use OFDM in packet-based communications.

The use of OFDM was previously limited to continuous transmission systems like digital audio broadcasting (DAB) and digital video broadcasting (DVB). Following the IEEE 802.11 decision, High-Performance LAN (HIPERLAN) type 2 and Japan's Multimedia Mobile Access Communication (MMAC) also adopted OFDM for their physical layer interface (PHY) standards. The three bodies have worked in close cooperation since then to ensure that differences between the various standards are kept to a minimum, thereby enabling the manufacturing of equipment that can be used worldwide.

Like the IEEE 802.11 standard, the European Telecommunications Standards Institute (ETSI) HIPERLAN type 1 standard specifies both media access control (MAC) and PHY. However, unlike IEEE 802.11, no HIPERLAN type 1 compliant products are available in the marketplace. A newly formed European Technical Standards Institute (ETSI) working group, Broadband Radio Access Networks (BRAN), is now working on the following extensions to the HIPERLAN standard: HIPERLAN type 2, a wireless indoor LAN with quality of service (QoS) provision; HiperLink, a wireless indoor backbone; and HiperAccess, an outdoor, fixed wireless network providing access to a wired infrastructure.

There are two main differences between HIPERLAN types 1 and 2. First, HIPERLAN type 1 has a distributed MAC without QoS provisions, while HIPERLAN type 2 does have these provisions using a centralized scheduled MAC. Second, the PHY of HIPERLAN type 1 is based on single-carrier Gaussian minimum shift keying (GMSK), while HIPERLAN type 2 uses OFDM.

OFDM is chosen primarily to combat the effects of multipath in the 5 GHz radio environment. The disclosed Broadband Wireless Home Network solution uses 256QAM as a basic modulation technique with a compliment of equalization and spatial diversity combining to combat the same multipath problems.

Although technically appealing, OFDM has its own set of complexities and difficulties to overcome before implementation is complete. The OFDM method described in 802.11a proposes the use of 52 quaternary binary phase shift keying (BPSK), or QAM carriers, to provide data rates from 6 to 54 Mbits/sec. <u>These data rates refer to a full burst rate and do not account for data rate inefficiencies that are introduced, for example, to allow reverse channel time slot insertion, round trip delays and timing/synchronization effects</u>.

A fully integrated OFDM design was shown in reference [1]. An estimated equivalent of 200,000 gates were used before the introduction of Forward Error Correction (FEC), Host Interface or other necessary interface and control circuitry. <u>The comparable NewCo QAM architecture is estimated to need less than 300,000 gates, thus requiring fewer overall gates to implement the same functionality</u>. OFDM, with its multi-carrier approach also places extreme linearity and dynamic range demands on the RF and analog signal processing circuits like the power amplifier, ADC and DAC. <u>OFDM adds cost over NewCo's approach</u>.

<u>Finally, the OFDM solution requires nearly twice as much spectrum to achieve an equivalent data rate</u>. Thus, only 16 full duplex channels can be anticipated per 200MHz band at 5.6GHz.